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Exploring the Nexus between the Blue Economy and Information Technologies: A Systematic Literature Review of Information Systems in Pacific Fisheries and Aquaculture

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Abstract

The blue economy has garnered significant importance over the years as a major driver for sustainable economic growth in the Pacific region through the efficient utilization of marine resources. While a thorough examination of the whole gamut of information about information and communication technologies (ICT) gains momentum, establishing a cohesive perspective on pivotal findings within blue economy research, particularly in fisheries and aquaculture, becomes essential for maximizing the potential of this interdisciplinary field. Consequently, Information Systems (IS) researchers, through a comprehensive review of pertinent literature, can contribute significantly to this emerging body of knowledge. Our review, which encompasses 32 papers published from 2012 to 2022, focuses on the application of information technologies to Pacific fisheries and aquaculture. The prevailing literature enhances our understanding of the adoption and utilization of ICTs (i.e. Geographic Information Systems (GIS), remote sensing and satellite imaging, database management systems and other emerging technologies) within the blue economy. In this paper, we provide discussions on recent technological advancements and future research directions to encourage IS researchers to develop an effective cumulative tradition of research.

Keywords: *blue economy, ICT, fisheries, aquaculture, Pacific Ocean*

The Pacific Ocean covers 30% of the Earth's surface and supports a diverse range of life forms while providing vital marine resources [1]. Despite the relatively low public awareness regarding its biodiversity and resources compared to terrestrial ecosystems, countries bear a responsibility to prioritize sustainable utilization of marine resources in line with the United Nation's 2030 Agenda for Sustainable Development. This obligation underscores the need to allocate both technical and financial resources to achieve a balance between the utilization and preservation of the oceanic domain [2]. Such commitment drives the emergence of the blue economy which advances the utilization of oceanic resources to engender sustainable economic advancement, enhanced livelihoods, and the well-being of marine ecosystems [3]. The blue economy encompasses a broad range of interconnected activities associated with bodies of water such as seas, and oceans. These activities include different sectors such as fisheries and aquaculture, maritime transport and shipping, marine biotechnology, offshore oil and energy exploration, coastal and marine infrastructure development, and marine tourism [4].

The economic significance of oceans and coasts cannot be overstated. These bodies of water are crucial for food security, poverty eradication, sustainable economic growth, and the preservation of traditional cultures and global trade. Oceans contribute significantly to the world's food supply, with aquaculture being the fastest-growing sector. This sector provides approximately 47% of global fish consumption [5] and supports 350 million jobs linked to marine fisheries [6]. The fisheries sector, a key component of the blue economy, contributes over $270 billion annually to the global GDP and provides indirect benefits worth around $2.5 trillion per year [7].

Spanning half of the Earth's oceans, the Pacific boasts unparalleled marine biodiversity which is responsible for 70% of global fish yield. For small island developing states in the Pacific, the fisheries sector is a vital source of nutrition, employment, and export earnings [8, 6]. In Asia and the Pacific particularly, a sustainable blue economy is a crucial policy objective, given the significant economic growth in coastal, archipelagic, and island nations over the past decade [9]. Preserving critical habitats, such as coral reefs and mangroves, is vital to protect tropical fisheries and vulnerable human communities [10]. Understanding the region's vulnerability and implementing effective management actions are essential to build ecosystem resilience and maintain ecosystem services [5].

Although the importance of Information Communications Technology (ICT) in optimizing food production has been underscored in recent literature [11], its specific impact and current utilization in fisheries and aquaculture in the Pacific Ocean remain unclear. In this paper, we review studies from the IS discipline on the blue economy in the Pacific region to provide an overview of the information technology and information systems research.

Blue Economy and ICT

The Changwon Declaration of 2012 defines the blue economy as a sustainable ocean-based economic model that utilizes environmentally friendly and innovative infrastructure, technologies, and practices. It aims to achieve inclusive development, protect coasts and oceans, address environmental risks, ensure water, energy, and food security, safeguard the well-being of coastal communities, and promote ecosystem-based climate change mitigation and adaptation [3].

To achieve these objectives, international organizations like APEC and OECD emphasize the significance of information and communication technology (ICT) and innovative strategies in fostering a sustainable ocean economy. They advocate that science and technology play pivotal roles in achieving both economic growth and ecological preservation within the blue economy. These efforts promote innovative management practices through the adoption of various technologies, with a shared goal of ensuring the sustainable utilization of ocean resources for current and future generations [12].

The blue economy's technological dimension as argued by Youssef [11] focuses on applying new technologies in marine robotics, sensors, AI, renewable energy, and biotechnology. Its principles revolve around promoting innovation, technology transfer, and responsible use. This approach encourages innovation, leading to new businesses and products serving ocean users' needs. New technologies like robotics and sensors have the potential to enhance efficiency and productivity while minimizing negative impacts on the ocean. Investments in scientific research, data, and technology are essential for supporting governance reforms and guiding management decisions that lead to more effective policies that facilitate lasting transformation [7].

Several Pacific countries have embraced technology for various purposes. For instance, Australia assisted Pacific Island nations in combatting illegal fishing through training and support for their officials [13], while China formulated its National Ocean Development Plan to expedite the adoption of advanced technology, aiming to revitalize marine sectors [13]. Moreover, in 2019, the Pacific Ocean Portal was established to provide easily accessible real-time and historical data for sectors like tourism, fishing, shipping, coastal inundation, and environmental management for Fiji, Palau, and other Pacific Island countries. The portal also includes training modules for users and incorporates stakeholder engagement workshops to accommodate requests for ocean information products from different sectors [14].

While the role of information technologies has been highlighted in the literature, there remains a notable gap in the Information Systems (IS) literature concerning their adoption and utilization in the fisheries and aquaculture sector, particularly in the Pacific region. In this paper, we aim to address this gap by reviewing IS studies related to the blue economy in the Pacific region. We aim to articulate the recent advances in the blue economy in order to answer the following research question:

RQ: What information and communication technologies (ICT) are currently being employed in Pacific Fisheries and Aquaculture?

To this end, the paper discusses the utilization of information technology in the Pacific fisheries and aquaculture, within the framework of the blue economy literature, to pave the way for future research.

Materials and Methods

To answer our research question, we conducted a systematic literature review, following the approach outlined by Lu et al., [15]. We searched existing research across multiple disciplines to create our sample of review. The review process included a keyword-based search in three indexing databases, a systematic selection of relevant papers, a forward and backward search on the papers of the subject-area screen, and the analysis of the selected paper, which is presented in Figure 1. We conducted searches in three digital libraries. First, Scopus, being one of the largest curated databases, encompassing peer-reviewed journals and other scholarly documents [16], was utilized in this study. Additionally, the AIS Electronic Library and ScienceDirect was included as these platforms are frequently utilized for systematic reviews within the field of Information Systems research [17]. We searched for titles and abstracts of English-language articles published in peer-reviewed journals and conference proceedings from 2012 to 2022 using the following terms: [“Blue economy” OR “fishery” OR “aquaculture”] AND [“Information System” OR “Information Communication Technology” OR “Information Technology”] and [“Pacific Ocean”]. A screening of articles was conducted based on a review of titles and abstracts, with researchers reading the full text when needed. The gathered articles were then evaluated based on their abstract, methodology, analysis, and conclusion and their relevance to the research questions. The focus of the literature review was on the empirical studies describing the technologies adoption/usage in the blue economy literature. Recent literature classified as book chapters, reviews, book, conceptual paper, an article in press, work in progress papers, short survey, note, master’s and doctoral thesis, retracted -paper, and other subject areas not related to the topic domain were excluded in the study. Also, non -English articles and studies with no ICT implementation in the aquaculture and fisheries sector in the Pacific Ocean were omitted. Further, this review excludes other papers that discuss physiological and marine species behavior.

The database search resulted in 785 studies. After removing the duplicates and irrelevant studies, 101 studies remained for further screening. We iteratively applied inclusion and exclusion criteria to further assess eligibility, resulting in 30 articles. After conducting forward and backward searching, two (2) articles were added resulting to 32 studies in the final article pools.

Results and Discussion

Technologies

In the blue economy, a variety of information systems are used to support decision-making, management, and monitoring of ocean-based activities and resources. Some of the key information systems used in the blue economy are shown in Table 1.

Geographic Information System (GIS)

Based on the results of the systematic literature review, the Geographic Information System emerges as a prominently employed technology within the blue economy. Recent literature shows that GIS is used to capture, store, manage, analyze, and visualize spatial and geographical data. Further, studies indicate that GIS serve as a pivotal tool for delineating the topographic features and landscapes of marine ecosystems [18, 19, 20], including the social and

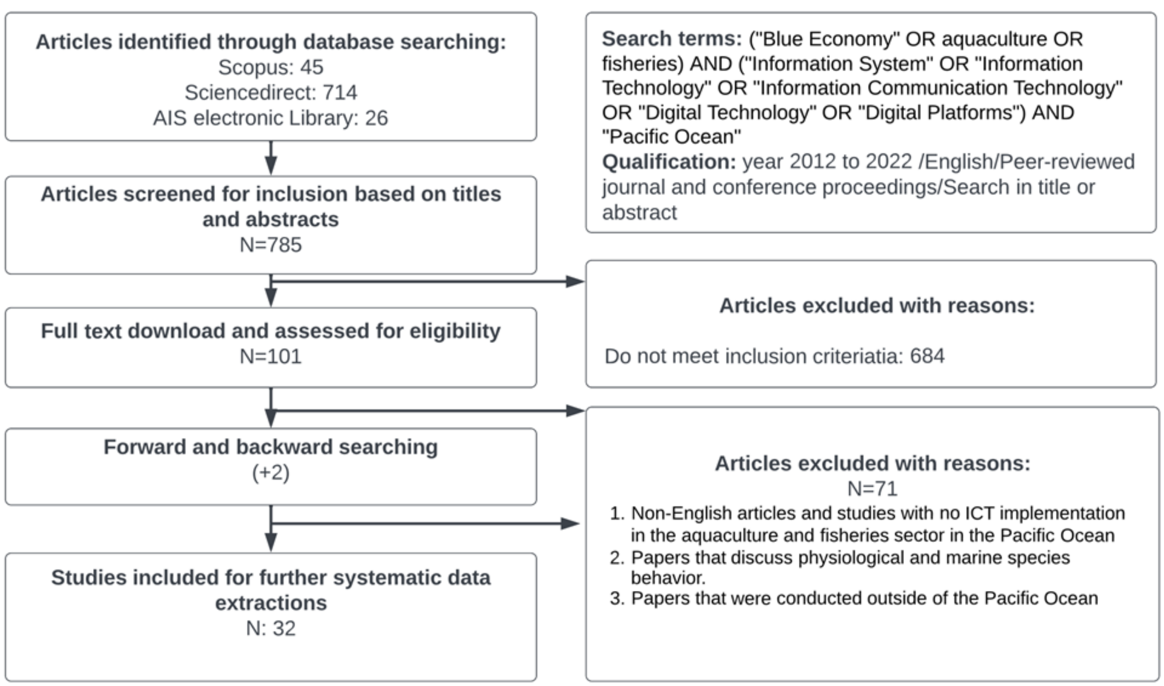

Figure 1. Framework Used for Systematic Literature Review in the Pacific Blue Economy Research (Adapted from Lu et al., 2015). This approach involved searching existing research across diverse disciplines to form our review sample comprised of keyword-based searches in three indexing databases (Scopus, ScienceDirect and AIS electronic library), systematic selection of relevant papers, both forward and backward searches on papers within the subject area, and subsequent analysis.

Table 1. Technologies used in blue economy research. This table outlines the diverse array of technologies employed in the pacific blue economy literature, accompanied by their respective references.

Technologies	References
Geographic Information System	(Breckwoldt et al., 2022; Cunningham et al., 2013; Sullivan et al., 2015; Alvarez et al., 2015; Arias et al., 2022; Gonzáles-Andrés et al., 2016; Yen et al., 2012; Wu et al., 2013; Salgado et al., 2018; Tharwat et al., 2018; Hu et al., 2020; Baker et al., 2019; Ban et al., 2013; Costanza & Francisco, 2021; Harrison et al., 2017; Léopold et al., 2014; Niu et al., 2012; Robb, Bodtker, & Wright, 2015)
Remote Sensing and Satellite Imaging	(Cunningham et al., 2013; Arias et al., 2022; Yen et al., 2012; Douglas et al., 2017; Wu et al., 2013; Salgado et al., 2018; Harrison et al., 2017; Ding, Zhang, & Shang, 2022; Liu et al., 2015; Oozeki et al., 2018; Tanaka et al., 2022; Zhou et al., 2016)
Database Management Systems (Ocean Observatories)	(Gonzáles-Andrés et al., 2016; Douglas et al., 2017; Wu et al., 2013)
Other technologies (Unmanned Underwater Vehicle, Automatic Identification System, Computer Vision)	(Douglas et al., 2017; Salgado et al., 2018; Liu et al., 2021; Tharwat et al., 2018; Yamakita et al., 2018; Hu et al., 2020; Oozeki et al., 2018)

cultural landscape through participatory GIS [21]. It also plays a crucial role in predicting fishing zones, habitat suitability, as well as the abundance and distribution of marine species [22, 23, 24, 25]. Furthermore, it assists in evaluating marine ecological stressors and assessing human and industrial disturbances [26].

Remote Sensing and Satellite Imaging

The review of the literature revealed the use of remote sensing technologies, such as satellite imagery and aerial photography, for data collection on oceanic and coastal environments. The collected data are utilized for monitoring changes in the marine environment, including ocean temperatures, and to support industries reliant on the ocean. Utilizing high-resolution satellite images, remote sensing techniques emerged as one of the most effective solutions for investigating shoreline, coastal zone changes over extended periods, as they offer efficiency, effectiveness, and access to temporal data. A notable advantage of these satellite images lies in the availability of both medium- and high-resolution options, along with access to time series data [27].

In the context of the blue economy, as displayed in Table 2, common marine ecosystem indicators derived from remote sensing, satellite imagery and other data repositories offer valuable insights into fishing activities and resource sustainability. Fishing Effort, defined as the number of boats per day per area or community [20], and Catch per Unit Effort, defined as the amount of catch obtained per unit of fishing effort expended [23, 25, 39], provide crucial data for assessing fishing practices. Furthermore, metrics such as Sea Surface Temperature, which varies significantly based on factors like latitude, season, ocean currents, activities, and weather patterns [24, 25, 42, 47], and sea surface salinity, referring to the concentration of salt in the water at the ocean's surface [25], offer valuable information for understanding oceanographic conditions. Moreover, bathymetry, the measurement of water depth in oceans, seas, lakes, or other bodies of water [19, 23, 48], and dissolved oxygen, the amount of oxygen gas dissolved in water [45], are essential parameters for assessing aquatic life and ecosystem health. Ocean organisms such as fish, invertebrates, and plants rely on oxygen for respiration, highlighting the importance of monitoring dissolved oxygen levels. Further, chlorophyll-a, a measure of the number of algae growing in a water body [23, 24, 25], serves as an indicator of ecosystem productivity and health. All these indicators play critical roles in monitoring ecosystem health, guiding marine practices, and informing decision-making for ocean-based economic activities.

Database Management Systems

Based on the findings of this literature review, there are existing databases that play a crucial role in managing and providing access to information about marine resources. These databases serve as valuable repositories of data that are essential for scientific research, policymaking, conservation efforts, and the sustainable management of marine ecosystems. For instance, One Network Canada's (ONC) Ocean 2.0 contains a geospatial database and toolkit that integrates

Table 2. Common ecosystem indicators used in the blue economy literature. It catalogues these indicators along with their respective references. These indicators include Fishing Effort, Catch per unit effort, Sea Surface Temperature (SST), Sea Surface Salinity, Bathymetry, Dissolved Oxygen, and Chlorophyll-a. The references highlight the widespread utilization of these indicators across studies, emphasizing their crucial role in the assessment and monitoring of marine ecosystems within the context of blue economy research.

Indicators	References
Fishing Effort	(Morzaria-Luna et al., 2020; Arias et al., 2022; Salgado et al., 2018; Léopold et al., 2014)
Catch per unit effort	(Arias et al., 2022; Yen et al., 2012; Léopold et al., 2014)
Sea Surface Temperature (SST)	(Gonzáles-Andrés et al., 2016; Yen et al., 2012; Ding, Zhang, & Shang, 2022; Feng, Chen, & Liu, 2017)
Sea Surface Salinity	(Yen et al., 2012)
Bathymetry	(Cunningham et al., 2013; Arias et al., 2022; Johnson et al., 2017)
Dissolved Oxygen	(Tanaka et al., 2022)
Chlorophyll-a	(Arias et al., 2022; Gonzáles-Andrés et al., 2016; Yen et al., 2012; Tanaka et al., 2022; Feng, Chen, & Liu, 2017; Petatán-Ramírez et al., 2020)

various data types to support the integration and management of remote and dynamic seafloor habitats [26]. Another example is the study of Gonzáles-Andrés et al., [24] who utilize the MARSPEC database for forecasting the abundance and distribution of marine species. This database contains ocean climate layers for marine spatial ecology. Similarly, the study conducted of Wu et al., [28] makes use of spatial and temporal data from the China's State Oceanic Administration (SOA) marine environment monitoring center database to investigate the occurrences of Harmful Algal Blooms (HAB). Further, other existing databases include the World Ocean Database, a product of the U.S. National Oceanographic Data Center and its co-located World Data Center for Oceanography. This database hosts the largest collection of uniformly formatted, quality-controlled, publicly available ocean profile data.

Other Technologies (Unmanned Underwater Vehicles, Automatic Identification Systems, Computer Vision)

Alternative technologies were employed for deep-sea surveys including unmanned underwater vehicles which are used in collecting marine resources [26, 29]. The Automatic Identification System (AIS), a ship-based transceiver system, was utilized by vessel traffic services. Liu et al. [30] harnessed AIS data to elucidate the marine ecological stress attributed to vessel activities, facilitating the development of a comprehensive index system. Moreover, advancements in computer vision techniques have enabled diverse studies to identify marine organisms [31, 32], their freshness, and quality [33], as well as the identification of the richness and fishing intensity [29].

Limitations of the Study

We acknowledge that our paper is not without limitations. The first limitation of this study lies solely on English language articles retrieved from Scopus, AIS electronic library, and ScienceDirect databases. The authors recognize the possibility that relevant studies might have been overlooked due to these strict inclusion criteria. Additionally, the review excluded book chapters and reports. Therefore, future studies may consider incorporating book chapters, exploring studies in other languages, and examining diverse academic databases. Secondly, although our review concentrated solely on studies within the Information Systems field, a comprehensive literature review aiming for a representative overview of the field should naturally involve domains from other disciplines as well. Finally, despite implementing thorough measures at different stages to ensure methodological rigor and review validity, it is important to acknowledge that this process involves subjective knowledge on the part of the authors and hence may not be as statistically rigorous or replicable as alternative methodologies like PRISMA in systematic literature reviews. Nevertheless, we consider this as an advantage of our selected methodology rather than a limitation.

Despite these limitations, the present Systematic Literature Review (SLR) offers a detailed account of emerging themes, research gaps and future direction in this domain. It is anticipated to serve as a foundation for future scholarly explorations in the field of blue economy. The results also paved the way for the emergence of several research directions. These directions offer exciting scholarly endeavours that can contribute value to the future of the blue economy.

Conclusion

The literature review findings presented in this study serve as a valuable resource for researchers and practitioners aiming to advance knowledge in support of the blue economy. While the exploration of various technologies in the Pacific blue economy is evident, the study underscores the persistent call from Information Systems researchers to continually expand and embrace emerging technologies to address contemporary challenges. It enhances our understanding of the adoption and utilization of Information and Communication Technologies (ICTs) in the blue economy, encompassing technologies like Geographic Information System (GIS), remote sensing, satellite imaging, database management systems, among other emerging nnovations. Also highlighted by the study is the confluence of the blue economy and information systems to represent a strategic alignment that harnesses technological advancements to drive efficiency, sustainability, and inclusivity in fisheries and aquaculture initiatives. As such, the nexus between the blue economy and information systems signifies a transformative synergy. By leveraging technological advancements, information systems contribute to the evolution of the blue economy in a manner that is not only economically viable but also environmentally sustainable. Through fostering efficiency, sustainability, inclusivity, innovation, collaboration, and informed decision-making, information systems play a central role in shaping a harmonious and resilient future for the blue economy.

The review findings indicate a strong focus on the North Pacific, with a particular concentration of research originating from highly developed countries. However, the diverse Pacific region holds unique ecosystems with distinct species and ecological dynamics. Expanding research beyond the North Pacific is crucial to understanding the broader area's biodiversity and ecological patterns. This comprehensive perspective can inform conservation strategies for fisheries and aquaculture, aid in resource management, and address challenges among nations situated in the Pacific region. Collaborative efforts across institutions and nations will foster a unified approach to protect the Pacific's ecological hotspots, migration routes, and areas vulnerable to environmental changes, benefiting global biodiversity conservation and sustainable practices for future generations, and promoting responsible and sustainable practices in the fisheries and aquaculture industries. Furthermore, a framework that fully accounts for the value of marine assets and the ocean economy is crucial to guide the sustainable development of ocean industries. An accounting system ensures sustainable management, economic valuation, and informed decision-making, thereby preventing overexploitation while facilitating responsible resource allocation. It also aids in monitoring compliance with regulations, assessing ecosystem health, and planning for the long-term preservation of oceanic assets. With current data and technologies, it is now possible for all countries to account for the value of their natural resources and integrate their worth into their national accounts, accurately reflecting the country's development and economic performance. Several countries employ technologies such as databases and Geographic Information Systems to monitor and manage their marine resources, which helps them capitalize their blue assets and make informed decisions that balance economic growth and environmental protection.

The findings of the literature review indicate that coastal fisheries dominate most of the literature. The prevalence of research on coastal fisheries can be attributed to factors such as their greater accessibility, economic significance for local communities, intricate interactions with terrestrial ecosystems, and technological limitations for deep-sea environments. Additionally, coastal fisheries often face immediate regulatory and management concerns, prompting heightened attention and funding compared to the relatively uncharted deep-sea realms. Moving forward, the evolution of deep-sea technologies promises significant advancements fuelled by innovations in robotics, autonomous systems, and data collection methodologies. These technological strides are poised to facilitate profound exploration, sustainable resource management, and a deeper comprehension of the vast and enigmatic depths of our oceans. With bolstered mapping, sampling, and real-time monitoring capabilities, an expectation arises for the revelation of new species, the discovery of untapped marine resources, and heightened insights into the effects of climate change on these distant ecosystems. Arguably, to ensure the sustainability of fisheries and aquaculture across coastal and open-sea domains, science-driven ecosystem management backed by precise and predictive monitoring is imperative. Furthermore, exploring emerging technologies such as the Internet of Things (IoT), Artificial Intelligence, computer vision, acoustic telemetry, spatial mathematical modelling combined with remote sensing, and blockchain holds immense promise and should be pursued ambitiously from coastal to open-sea environments.

Authors' Contributions

JMC presented the idea of the Blue Economy. The final manuscript was written and edited by JMC and LJPD. All the authors carried out the literature review process and provided critical feedback that helped shape the research, analysis, and manuscript.

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